International Journal of Mechanical Engineering and Technology (IJMET)
Volume 8, Issue 2, February 2017, pp. 263–270 Article ID: IJMET_08_02_032
Available online at http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=2
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

MULTIPHASE SIMULATION OF AUTOMOTIVE HVAC EVAPORATOR USING R134A AND R1234YF REFRIGERANTS

C.S. Rajamanickam
Student, Vellore Institute of Technology, VIT- University, SMBS, Chennai, Tamil Nadu, India

P. Tamilselvan
Associate Professor, Vellore Institute of Technology, VIT-University, SMBS, Vellore, Tamil Nadu, India

ABSTRACT

This paper presents a multiphase simulation of evaporator in automotive air conditioning system was done by using R134a and R1234yf as working fluid (refrigerants) to know the performance parameters. A CFD model was built to simulate the multiphase flow and the Thermal analysis is carried out for the evaporator by using R134a and R1234yf refrigerants with constant mass flow rate. The results obtained after the simulation are expressed in the figures of volumes fraction, temperature, velocity of refrigerants. The CFD simulation was compared with both the refrigerants. And it was also thus conforming that the CFD model was successful in reproducing the heat and mass transfer process in HVAC evaporator using R134a and R1234yf refrigerants.

Key words: Multiphase, R134A, R1234yf, Thermal analysis, HVAC, Evaporator, Star ccm+.

Cite this Article: C.S. Rajamanickam and P. Tamilselvan. Multiphase Simulation of Automotive HVAC Evaporator using R134A and R1234YF Refrigerants. *International Journal of Mechanical Engineering and Technology*, 8(2), 2017, pp. 263–270.
http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=8&IType=2

1. INTRODUCTION

Evaporator is one of the necessary components of HVAC system. The refrigerant can be considered as the fifth most important component. The design of evaporator changes based on the application. And the refrigerants used here absorb the amount of heat proportional to the latent heat of evaporator. This is sufficient to change its phase from liquid to gas in the evaporator.

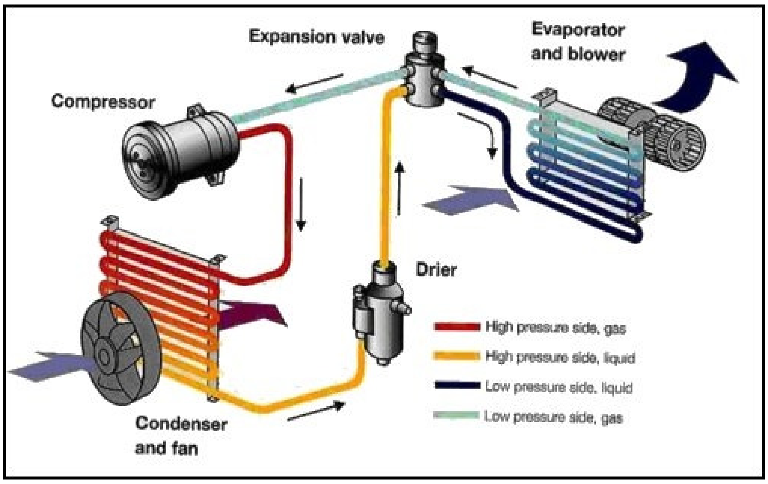


Figure 1 Evaporator Flow chat

In the evaporator, the refrigerant is evaporated by the heat transferred from the heat source. The heat source will be a gas during evaporation, the Temperature of a pure refrigerant is constant, as long as the pressure does not change.

1.2. Vapour Compression Cycle

The system uses refrigerants like R-11, R12, R22, R134a. The system mainly consists of four parts Compressor, Condenser, thermal Expansion Valve, and Evaporator. When compressor is started, it draws the low pressure vapour from the evaporator to the compressor and compresses it entropically high pressure to the condenser. Hence the vapour temperature also increases. Then the hot vapour from compressor is passed to condenser, when it is cooled, rejects heat and hot vapours get converted into liquid. Then it passes from expansion valve which reduces pressure of liquid, thus liquid gets converted into vapour of low dryness fraction. Finally Low pressure, low temperature refrigerant passes through evaporator, where it absorbs, and its latent heat from cold chamber and gets converted into vapour, thus the entire vapour compression cycle works in the Automobile HVAC. Air conditioning's main principles are Evaporation and Condensation, then Compression and Expansion.

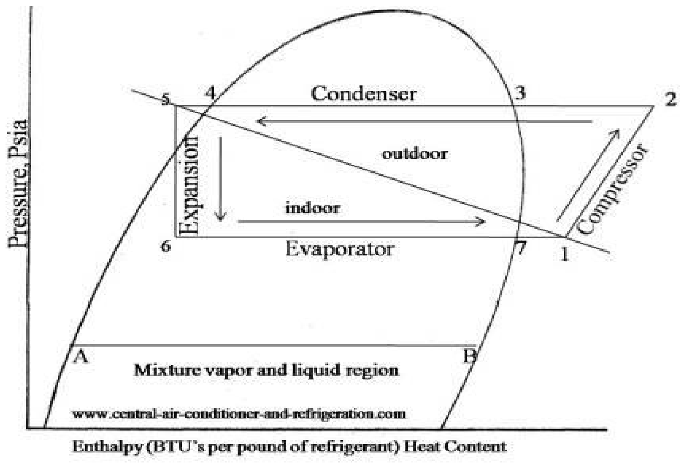


Figure 2 Vapour compression cycle

1.3. Refrigerants

The new technology's brought many environmental problems. The refrigerant that we use in HVAC affects the ozone layer and global warming. As the chlorine atoms present in the refrigerant causes damage to the ozone layer, it was limited to use of refrigerants that contain chlorine atoms. The usage of

hydroflurocarbons group refrigerants will be banned gradually, which is having high global warming potential (GWP), R1234yf refrigerant is having low GWP no intoxicant.

Table 1

	R134A	**R1234yf**
Ozone Depleting Potential	0	0
Global warming potential	1430	4
Boiling temperature at 2 bar	-10.1^{o}c	-12 ^{o}c
Atmospheric Lifetime (Years)	14	0.03

2. EXPERIMENTAL DETAILS

2.1. Geometry

The CAD model was developed by using CATIA to simulate the multiphase flow and heat transfer phenomena

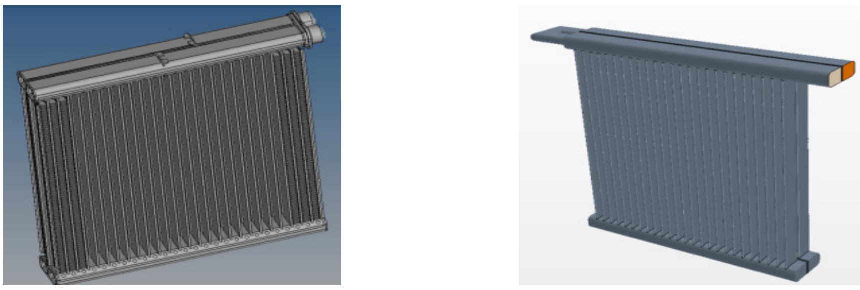


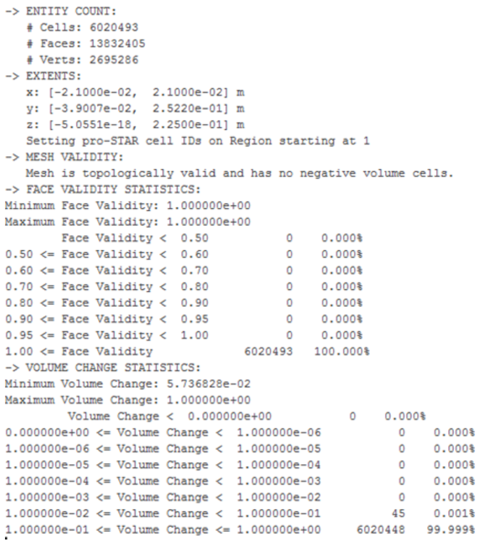
Figure 3 Evaporator CAD model

2.2. Mesh

The Meshing for the designed model was done in STAR CCM+. Total entity count of 6020493, near the right and left walls eight boundary layers are used to capture thin liquid film that develops in the region. The base size of 0.01mm.

Figure 4 Mesh

Grid independence test needs to be run.This test also assures us of the quality of the mesh and the size of the elements.



```
-> ENTITY COUNT:
   # Cells: 6020493
   # Faces: 13832405
   # Verts: 2695286
-> EXTENTS:
   x: [-2.1000e-02,  2.1000e-02] m
   y: [-3.9007e-02,  2.5220e-01] m
   z: [-5.0551e-18,  2.2500e-01] m
   Setting pro-STAR cell IDs on Region starting at 1
-> MESH VALIDITY:
   Mesh is topologically valid and has no negative volume cells.
-> FACE VALIDITY STATISTICS:
Minimum Face Validity: 1.000000e+00
Maximum Face Validity: 1.000000e+00
        Face Validity <  0.50           0    0.000%
0.50 <= Face Validity <  0.60           0    0.000%
0.60 <= Face Validity <  0.70           0    0.000%
0.70 <= Face Validity <  0.80           0    0.000%
0.80 <= Face Validity <  0.90           0    0.000%
0.90 <= Face Validity <  0.95           0    0.000%
0.95 <= Face Validity <  1.00           0    0.000%
1.00 <= Face Validity             6020493  100.000%
-> VOLUME CHANGE STATISTICS:
Minimum Volume Change: 5.736828e-02
Maximum Volume Change: 1.000000e+00
         Volume Change <  0.000000e+00          0    0.000%
0.000000e+00 <= Volume Change <  1.000000e-06         0    0.000%
1.000000e-06 <= Volume Change <  1.000000e-05         0    0.000%
1.000000e-05 <= Volume Change <  1.000000e-04         0    0.000%
1.000000e-04 <= Volume Change <  1.000000e-03         0    0.000%
1.000000e-03 <= Volume Change <  1.000000e-02         0    0.000%
1.000000e-02 <= Volume Change <  1.000000e-01        45    0.001%
1.000000e-01 <= Volume Change <= 1.000000e+00   6020448   99.999%
```

Figure 5 Quality Check

2.3. Physics

The problem comes under Multiphase as there is two phases in the same system i.e. Liquid to gas (evaporator inlet is liquid refrigerant and the outlet is gas refrigerant).we have constant mass flow throughout the system (evaporator) The Volume of Fluid (VOF) model is provided for the system containing two or more immiscible fluid phases, where each phase constitutes a large structure within the system

3. RESULTS AND DISCUSSIONS

3.1. R134a

3.1.1. Velocity Plots

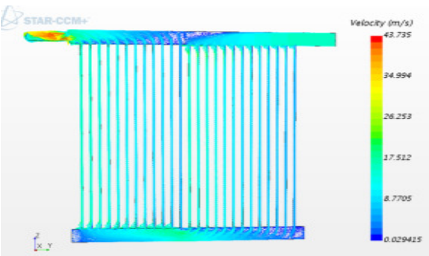


Figure 6 1st and 2nd pass

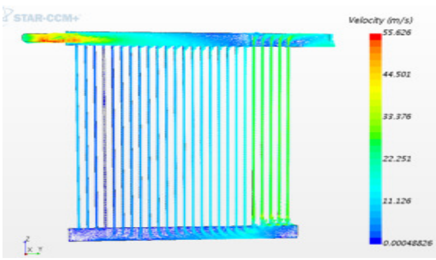


Figure 7 3rd and 4th pass

Figure 8 Entire Evaporator

3.1.2. Temperature Plots

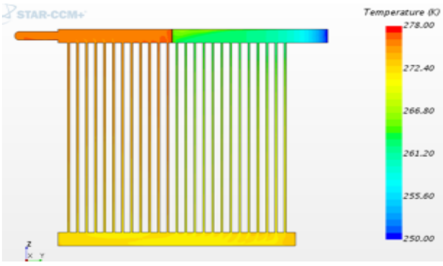


Figure 9 1st and 2nd pass

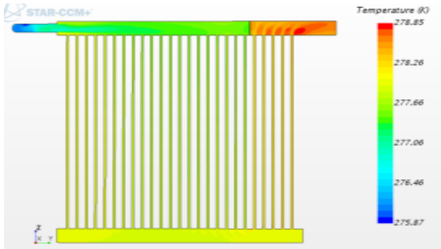


Figure 10 3rd and 4th pass

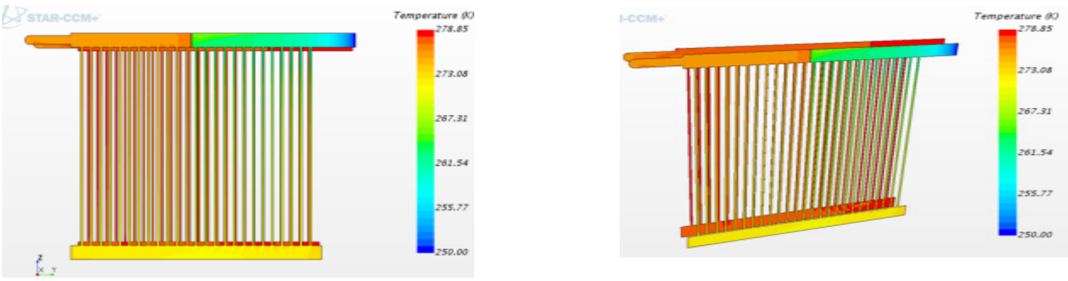


Figure 11 Entire Evaporator

3.1.3. Volume Fraction of Gas R134a

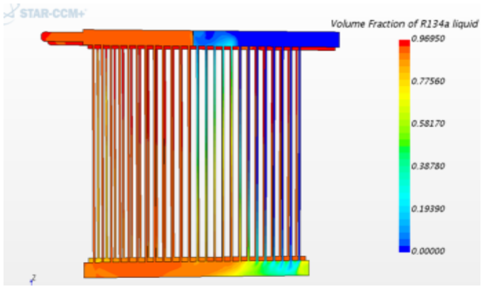


Figure 12 Entire Evaporator

3.2. R1234yf

3.2.1. Velocity Plots

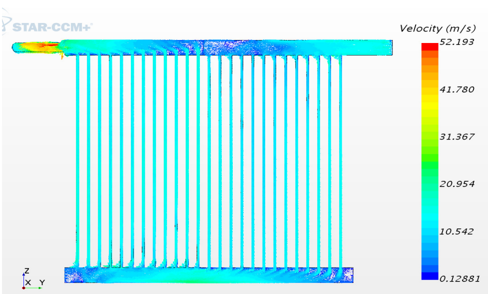


Figure **13** 1st and 2nd pass

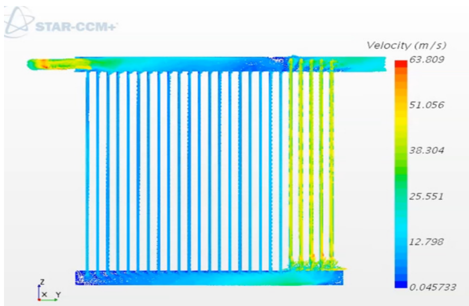


Figure 14 3rd and 4th pass

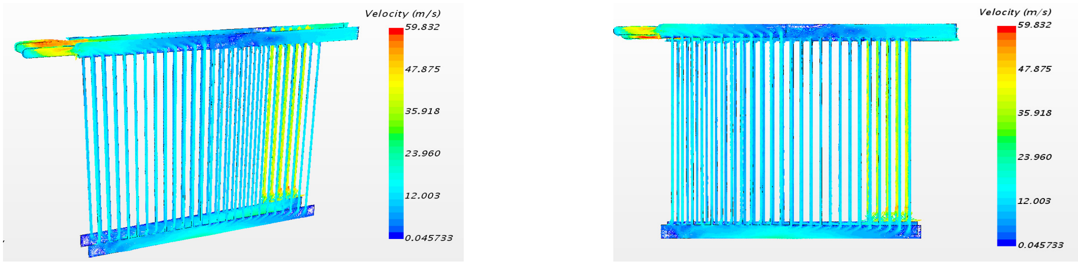


Figure 15 Entire Evaporator

3.2.2. Temperature Plots

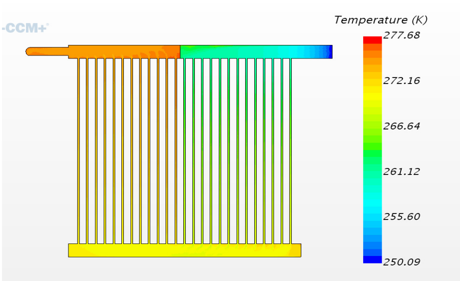


Figure 16 1st and 2nd pass

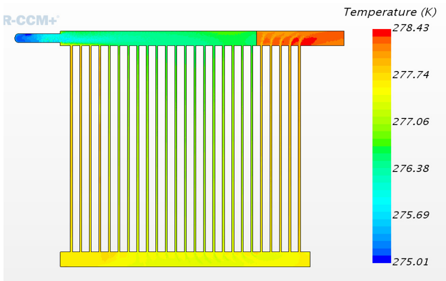


Figure 17 3rd and 4th pass

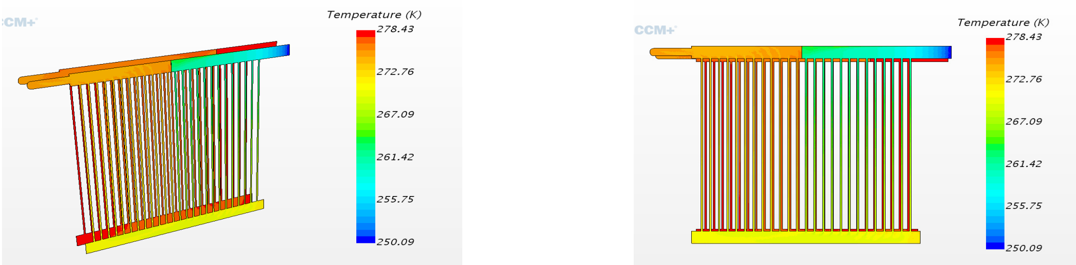


Figure 18 Entire Evaporator

3.3.3. Volume Fraction of Gas R1234yf

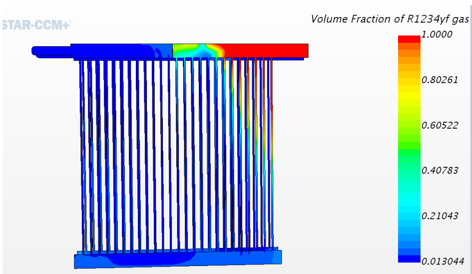


Figure 19 Entire Evaporator

4. CONCLUSION

In the present study multiphase simulation of automotive HVAC was done by using R134a and R1234yf refrigerants. Thermodynamic properties of both the refrigerants were taken at Constant pressure and a constant mass flow rate was maintained for both the refrigerants and the results were compared,

Also it was observed that the R1234yf refrigerant has less COP and less cooling capacity than R134a refrigerant.

5. ACKNOWLEDGEMENT

My sincere gratefulness first goes to my guide, Tamilselvan P, Associate Professor-SMBS, for his help, support and inspiring guidance.

REFERENCES

[1] D.O Esen, M.Hosoz, Experimental performance analysis of an automobile air conditioning system using refrigerants R12 and R134a,International journal of the Faculty of engineering and architecture, 21(4):703-709, (2006)

[2] Hashim Sahar Mohaisen, Dr.E.Ramjee, Modelling and thermal analysis of air conditioning evaporator, International Journal of Scientific engineering and Technology Research (2014), 4156-4160.

[3] Omar M.Al-Rabghi,Abdulkareem A.Niyaz,Retrofitting R-12 car air conditioner with R-134 refirgerant, International journal of Energy Research, 24(6):467-474 · MAY 2000

[4] Bandar Fadhl, Luiz, C.Wrobel, Hussam Jouhara, CFD Modelling of a two phase closed thermosymphon charged with R134a and R404a, Applied Thermal Engineering, Elsevier(2015), 482-490.

[5] Alpaslan Alkan, Ahmet Kolip, Sertac Cosman, Thermaodynamic analysis of an automotive air conditioning system using R1234YF and R134a, The Sixth International Energy and Environment Symposium (IEEES-6), At Recep Tayyip Erdoğan University Rize, Turkey.

[6] Claudio Zilio, J.Steven Brown, Giovanni Schiochet, Alberto Cavallini, The refrigerant R1234YF in air conditioning Systems, Elsevier(2011), 6110-6120.

[7] Piotr A. Domanski, David Yashar,Minsung Kim , Performance of a finned tube evaporator optimized for different refrigerants and its effect on system efficiency, International conference of refrigeration 28, Elsevier (2005), 820-827.

[8] Claudio Zilio, Riccardo Brignoli, Norbert Kaemmer, Bachir Bella , Energy efficiency of Reversible refrigeration unit using R410A and R32. International journal for science and technology for the built environment (2015), 502-514.

[9] Tomoichiro Tamura, Yuuichi Yakumaru, Fumitoshi Nishiwaki, Experimental study on automotive cooling and heating air conditioning system using CO2 as a refrigerant, International Journal of Refrigeration 28 (2005), 1302-1307.

[10] Kiran.B.Parikh, Tushar.M.Patel, Analysis and validation of fin tube evaporator, International Journal of application or innovation in engineering and Management(2013),2319-4847

[11] Sanjay B.Pawar, A.S.mujumdar, B.N.Thorat, CFD analysis of flow patteren in the agitated thin film evaporator,Chemical engineering research and design (2012), 757-765.

[12] Pamela Reasor, Vikrant Aute, Reinhand Radermacher ,Refrigerant R1234yf Performance comparison Investigation, International Refrigeration and air conditioning conference at Purdue , (2012), 12-15.

[13] Bernardo Peris, J.M.Mendoza Miranda, Jaun Manuel Belman, Shell and tube evaporator model performance with different two phase flow transfer correlations. Experimental analysis using R134a and R1234yf, Applied Thermal Engineering,(2013).

[14] Yunus cengel and Ghajar, Heat and mass transfer, Fourth edition.

[15] M.Li, Chaobin Dang, H.Eiji, Study of flow boiling heat transfer of R32 in smooth horizontal tubes with various inner diameters, January(2012).

[16] Parthiban Kasi, Simulation of Thermodynamic Analysis of Cascade Refrigeration System With Alternative Refrigerants. *International Journal of Advanced Research in Engineering and Technology (IJARET).* 6(1), 2015, pp.71–91

[17] G.A.Longo, Simone Mancin, Giulia Righetti, Claudio Zillo, Saturated flow boiling of HFC134a and its low GWP substitute HFO1234ze(e) inside a 4mm horizontal smooth tube, . International journal for Refrigeration and air conditioning, January (2016).

[18] N. Bhagat and Shashi Kant, Amit Tiwari, Advanced Tool for Fluid Dynamics-CFD and its applications in Automotive, Aerodynamics and Machine Industry. *International Journal of Mechanical Engineering and Technology*, 7(2), 2016, pp. 177–186.

[19] Alptug Yataganbaba, Aki Kilicarslan, Irfan Kurtbas, Energy analysis of R1234yf and R1234ze as R134a replacements in a two evaporator vapour compression refrigeration system, International Institute of Refrigeration, December (2015), 26-37